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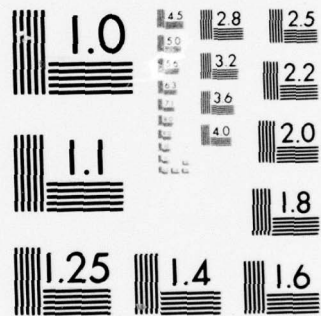UNCLASSIFIED .   TRG-023-TM-66-22   NL

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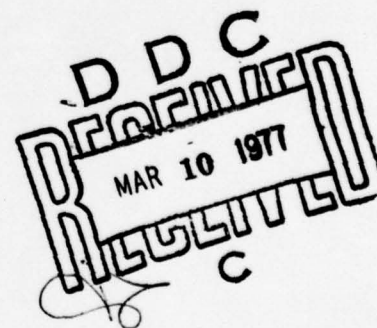
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FAULT ISOLATION AND SELF-CHECKING (FISC)
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MAY 1966

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FAULT ISOLATION AND SELF-CHECKING (FISC) EQUIPMENT
IN C/P SONAR

by

D. Cox

TRG Report No.-023-TM-66-22

Contract No. N0bsr-93023

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1.0   GENERAL

A system of the complexity of the C/P Sonar requires thorough analysis and planning of equipments and procedures required to maintain the equipment at peak operational readiness at all times. Since many approaches to fault detection, fault location, and system performance are possible, the ultimate selection of a philosophy and its hardware implementation will be based on system cost-effectiveness and be subject to constraints of Navy electronics maintenance philosophy for new ship construction in the 1970's.

1.1   FAULT ISOLATION AND SELF-CHECKING (FISC) GOALS

The present (FISC) effort is to assure that self-checking and fault isolation functions are given proper consideration during the GF (concept formulation) phase, prior to definition, as well as to assure suitable specifications for FISC functions for the ESS.

The objectives of the FISC effort are to produce the necessary documentation for both CD and ESS. This documentation will define suitable FISC approaches together with an explanation why alternate approaches are not recommended. Different FISC configurations will be compared in terms of:

1.   Capability to maximize system availability (minimize down time) within cost effectiveness constraints.

2.   Capability to generate user confidence in FISC, so maintenance personnel will use FISC.

3.   Capability to reduce personnel requirements.

4.   Capability to assist in estimates of shipboard performance level.

5.   Capability of use as tool in corrective and preventive maintenance.

1.2   EFFECT ON SYSTEM AVAILABILITY

The degree of automation of a self-check and fault isolation system, as well as the component level to which automatic fault location is made, has a major effect on mean-time-to-detect a fault and on mean-time-to-repair (MTTR). The sonar availability model, and therefore the sonar performance and cost-effectiveness models are dependent on these factors. Each of the subsystem models (active, passive, etc) has a number of inter-connected blocks, and each block has fully operative as well as degraded modes of operation. System performance is different for each of the states of these blocks. An overall measure of system performance is an average of performance in each of the many possible states weighted according to the probable percentage of time that a subsystem will exist in a given state.

When test parameters have been established for each component, several FISC approaches will be established. These approaches will differ from each other in terms of degree of automation, test schedule, level of equipment to which isolation is performed and cost. The component and subsystem availability is a function of the degree of automation, test schedule and test level. The cost of implementation will be related to the availability resulting from each FISC approach. The relationships will be tabulated in matrix form for comparative evaluation and selection of the best FISC approach.

1.3   NEED FOR SEVERAL ITERATIONS

Since the effect of different levels of self-test capability on systems cost effectiveness will not be available for several months to come, it is important that some initial definition of self-test and fault isolation be selected using reasonable engineering criteria, so that hardware definitions can be completed in time to develop specifications for the ESS. As system effectiveness and cost-effectiveness measures are developed, and as Navy maintenance criteria are taken into account, iterations of the initial approach may be required, especially for concept formulation documentation.

1.4   INITIAL ITERATION

The initial iteration for self-checking will be limited to end-to-end checks of certain components, or perhaps combinations of components, that have been relatively well developed. These identified components are power drivers, transmit-receive switches, receiving preamplifiers, and transmit and receive beamformers.

A meeting of contractors will be held to determine initial FISC requirements (meeting scheduled for May 18, 1966). Contractors responsible for an identified component will present reasonable stimuli and sensing requirements. These will be reviewed by PTD, NASL, and TRG and a recommendation made whether implementations in each case should be by special purpose generators and sensors that are to be an integral part of the component, or whether stimuli and responses will be external to the component. Preliminary consideration will be given to tests at lower level than end-to-end.

As an example of the type of approach that might be used, the following questions regarding driver amplifier testing ought to be considered:

1.   What are significant parameters? Output level, phase shift, power supply drain, etc. Which of these ought to be tested?

2.   How frequently must all amplifiers be tested? (This ought to be related to the amplifier MTBF and the probability that at any given time at least some fixed percentage of all amplifiers, say 90% or 95%, are operative.)

3.   Should the amplifiers be tested as part of their normal operation? If so, are the test results sampled in real time, or are they stored? (A simple storage scheme might be a set of lights, visually inspected at prescribed intervals.) If all amplifiers are tested simultaneously, an n-position scanner is required, where n will be a few thousand.

4.   Should tests be driver plus T-R switch plus
      transducer tests rather than driver tests? Or
      some other combination?

The above are indicative of the types of questions
to be considered and do not represent a complete approach to
all the factors involved in driver test considerations. Each
of the contractors will present his best preliminary thinking
in his area of cognizance at the May meeting. The material
will then be reviewed by PTD, NASL, and TRG and further in-
dividual meetings held as appropriate. TRG will present a
preliminary FISC plan for the identified components by the
end of June.

1.4.1 Receiver Test Considerations

Another example of preliminary test considerations
for the sonar receiver is given here.

The receiver consists of two banks of about 2700 re-
ceiving elements. Each receiving element includes a transducer,
a transmit-receive switch, and a preamplifier connected in a
series path. Failure of any one of these components causes the
loss of one receiving element. The loss of a single receiving
element involves a negligible performance degradation. Per-
formance simulations have shown that acceptable performance
can be maintained with as many as 10% of the elements inoperative.

The insensitivity of the overall receiver performance
to single or small numbers of element failures provides some
latitude in the receiver tests.

A signal tracing technique of receiver testing may
be implemented by inserting a stimulus into the receiver at
the element, at the T/R Switch, and/or at the preamplifier.
For purposes of self-check, the outputs of the preamplifiers
may be measured. During fault isolation, the three output
points of the circuit might be measured in succession. For
n=several thousand elements, a multi-thousand position scanner
may be required to check the results of such a test. If a
multi-thousand connection scanner raises reliability problems
of its own, consideration ought to be given to testing only a
few of the elements, say k, at a time by applying signals to

groups of k elements at times other than normal receive times.
Then the test outputs can be connected on k leads, each lead
tied to $\frac{n}{k}$ preamps. Now $\frac{n}{k}$ test cycles are required till all
elements have been checked, but the output scanner has been
reduced in size from n to k at the expense of special input
circuits to the elements and extra programming (which could be
done by special equipment or in the sonar data processor) to
sequence the tests.

Another possible approach to receiver testing con-
sists of a background noise or reverberation measurement tech-
nique. Noise and reverberation levels are reasonably constant
over small areas of the array. Using this technique, the noise
levels from a selected group of receiver elements are averaged.
The level from each element in the group is then compared to
the average. Any element which shows a wide variation from
the average is likely to be operating improperly. These measure-
ments would be made at the output of the preamplifiers and a
fault indication would indicate failure of the receiving ele-
ment rather than failure of a component of the element.

1.4.2   Transducer as a Transmitter

Some methods of testing the transducer as a receiver
have been indicated. It may be impossible to infer transducer
performance as a transmitter from the receiver measurements. It
is possible to infer transmission performance from the trans-
ducer impedance. Broad variations in the electrical impedance
of the transducer occur as the transmitted beam is steered from
broadside to endfire. A dynamic measurement of impedance dur-
ing transmission will indicate transmission performance. If
the electrical impedance fails to change adequately with steer-
ing this indicates a malfunction.

2.0 FISC PROGRAM

A longer term program of study and FISC synthesis to achieve a definition of FISC for both ESS and CF documentation by the end of this calendar year requires close coordination between NEL, NASL, and the C/P array contractors. TRG will provide the inputs to various system models, and together with NEL and NASL, arrive at a recommended overall FISC system. The nature of FISC will require coordination in the areas of system philosophy, maintenance philosophy, human engineering, logistics, personnel capabilities and requirements. Maintenance philosophy is heavily dependent on mechanical aspects of equipment design and will, therefore, require close cooperation with the mechanical aspect of the systems integration effort. The proper design of displays for FISC requires intimate knowledge of C/P display usage.

2.1 CONTRACTOR (GD/E, GE, TRG) CONTRIBUTIONS AT COMPONENT LEVEL

Each contractor responsible for a component function in the C/P Sonar must, at the earliest possible time, examine his component for FISC requirements. Without reference to specific implementation, each contractor should initiate a study that will provide data outlined below for his component. This data will be reviewed by TRG to determine the minimum number of stimuli generators and data sensors required for the entire FISC equipment. Requests for alternate approaches may be made by TRG in an attempt to minimize the number and types of generators and sensors that will be required. TRG will also review the requirements for testing sequences with a view to minimizing computer requirements, and system down time due to FISC operations.

Basic information required from each contractor for his components consists of the following:

1. Specification of stimuli and responses for end-to-end testing of the component (signal levels, impedances, frequencies, tolerances, etc.) should be included.

2. Program for fault-isolations after fault detection in end-to-end test.

3. Specification of stimuli and responses for tests to lower levels than end-to-end test.

4. First cut approximations of test schedule (frequency and sequence of tests). These must be related to component MTBF, in accordance with criteria furnished by reliability studies.

5. Duration of each test.

6. Special requirements for test data results on the FISC displays.

7. Extent to which normal component usage is compromised during test execution.

8. Recommended method of application of stimuli.

9. Effect of test signal input and output circuits on component MTBF.

10. In addition to a first cut recommendation for FISC, suggest two alternates: one to a lower level of faulty part identifications, one to a higher level. The effect of these three levels is to be compared in terms of component availability. In addition, curves are desired which, with the recommended sequence of testing, show the effect on component availability of variations in the frequency of testing.

11. For each component, a reasonable set of degraded
    modes of operation is to be defined. For each of
    these, the contractor is to compute the probable
    percentage of time that the component will be in
    the degraded state, as a function of
    a. level of fault location and
    b. frequency of test cycle.

12. A tabulation of estimated test point requirements
    should be made, with the test points classified as
    those required for end-to-end component tests, and
    those required for lower level tests.

2.2 DETERIORATING PARTS

An effort should be made to use the FISC system not
just as a go-no-go indicator, but to use measured test outputs
as indicators of incipient failure. This type of usage may
require considerable added computer capacity and must be
weighed in terms of its impact on cost-effectiveness.

2.3 BASIC FISC ALTERNATIVES TO BE CONSIDERED

TRG will coordinate with the other contractors the
test requirements for all components in the definition of the
necessary stimuli generators, sensors, test schedules, go-no-
go criteria, computer requirements, and desired display methods.

This will be achieved by coordinating the various
component test requirements, which are, at least initially, INDEPEN-
DENT OF THE SPECIFIC IMPLEMENTATION APPROACH.

The most basic questions regarding specific implemen-
tation are:

1. Are all checkout equipments, i.e., stimuli generators,
   sensors, computer control, displays to be integral
   with the components or

2. Are all these to be part of separate external
   equipment or

3. A combination of (1) and (2)

4. Is FISC control to be in the same data processor as tactical sonar control and operation? (This will be referred to an Integral Central Control.)

5. Is a separate data processor to be used for FISC?

2.4 TRG EFFORT

2.4.1 FISC Block Diagram

TRG will develop a FISC functional block diagram showing the types of signals to be inserted at various locations and types of signal to be sensed, throughout the system.

2.4.2 Stimuli Generators and Sensors

Based on various component requirements, the minimum number of stimuli generators and sensors will be defined. Compatibility with the internal circuitry of each of the components will be established.

2.4.3 Test Schedules

A table of test schedules will be maintained up to date. Flow charts showing subroutines will be produced and maintained.

2.4.4 Fault Isolation Time/MTTR

For each component, fault isolation time and MTTR will be studied as a function of both maintenance philosophy for that component and the level of automaticity of FISC applied to that component. For each component, a matrix will be established relating degree of automaticity to cost.

2.4.5 User Confidence: Reliability of FISC

It is absolutely vital that the sonar crew develops confidence in FISC. If this is not achieved, the system availability derived through FISC will be degraded--and the

investment made in FISC will be partially wasted. FISC design
must minimize false alarm rates. Positive indications that
major performance test cycles have been successfully completed
ought to be provided. Criteria for reliability of FISC
equipment and reliability acceptance tests for FISC will be
established. Periodic FISC self-performance tests will be
prescribed.

2.4.6 Personnel Requirements

Both operator and maintenance personnel require-
ments are affected by the FISC Subsystem. Together with NEL
and NASL specific goals will be established for the main-
tenance personnel complement and training requirements for
support of the sonar system. Realization of these goals will
depend,to a great extent, on the implementation of FISC.

2.4.7 Performance Degradations

FISC will be designed so that on malfunction de-
tection, a suitable input will be provided to the system
performance monitor.

Studies will include consideration of performance
degradation measurements. FISC will be designed to alert
maintenance personnel to conditions indicating impending
failure where such measurements are feasible and when the
failure would be critical to performance.

2.4.8 Preventive Maintenance

Certain normally scheduled preventive maintenance
tasks can be performed using the FISC tests. The additional
requirement on the FISC subsystem is for display of absolute
values of tested parameters in addition to Go-No-Go results.
This is essentially the same requirement as for performance
degradation monitoring.

3.0   TESTING STRUCTURE

The tests required to accomplish the total FISC
task will consist of a number of types. These include sub-
system end-to-end tests, equipment end-to-end tests, equip-
ment interface tests and component function tests. All
required tests must be included in an integrated FISC system.
It is necessary to divide the tests into those required for
performance monitoring or self-check and fault isolation.

3.1   FAULT ISOLATION TESTS

Fault isolation tests are initiated only after a No-Go
result from some self-check tests. These tests will be design-
ed to isolate the failure to some specified level of replaceable
assembly. The level to which fault isolation is carried will be
a function of effect on availability, equipment construction,
and test system cost.

3.1.1 FISC Processor

A detailed definition of the FISC processor will be
established. The functions of the processor include:

- Test scheduling and sequencing.
- Conditioning of stimuli generators.
- Limit parameter definition.
- Comparison of measured values and limit values.
- Go - No Go decision.
- Generation of display data.

The implementation of these central functions can be
accomplished in either of two basic configurations. The FISC
functions can be performed in the same processor used for
sonar data processing (integral control) or in a separate pro-
cessor (separate control).

Studies will be performed to evaluate the advantages
of each implementation. The configuration accompanying these
alternatives is described below.

3.1.2 Integral Control

Integral control has two primary advantages: less equipment is required and coordination problems are minimized. The major disadvantages are difficulty of programming and possible real-time schedule limitations.

The program for the central computer must contain both tactical functions and testing functions. Since a single processor controls all operations, the tests are inherently coordinated with the tactical operation. This condition applies only to those self-check tests made on a repetitive basis during tactical operation. Fault isolation and single-cycle demand tests could be performed by separate programs, to be run with limited or discontinued tactical operation.

3.1.3 Separate Control

If the operations of the FISC data processor are separate from the tactical functions (except for schedule coordination), the test programs are written separately, simplifying the programming task. Test schedules are controlled by the FISC processor subject to tactical schedule limitations.

Such a configuration provides the capability of performing high priority portions of the tactical functions in the FISC data processor if the tactical processor malfunctions.

Studies of the relative advantages and disadvantages of separate versus integral central control will be undertaken during the FISC study activity.

4.0   STATE OF THE ART STUDIES

A survey of self-check and fault isolation practices in systems in the advanced development stage will be made. Practices used in systems such as the SPS-48 radar, the SQS-26 sonar, and perhaps others will be reviewed. The technology developed as part of the TEAMS on-line equipment and VAST off-line equipment or similar equipment developed by NEL will be investigated for possible methodology applicable to C/P sonar FISC equipment.

5.0   LOWER-LEVEL TEST REQUIREMENT STUDIES

The function, configuration, design and packaging of each equipment should be considered to determine the level of fault isolation required. These studies should determine the *time required for isolation*, cost of implementation, personnel training, logistics requirements, and effect on availability associated with each possible level of fault isolation. These levels are defined as component, major assembly, minor assembly, lowest replaceable sub-assembly and piece part (where practical or where the lowest replaceable subassembly cost is in excess of its repair cost).

Estimates of separate, on-board trouble shooting and repair equipment and fixtures will be made for those levels of fault isolation other than lowest replaceable subassembly or piece part.

6.0   FISC SPECIFICATIONS

Complete FISC specifications for both ESS and CF documentation will be the final output of this effort.